WALSH

The History of Steel Railway Rails

Civil Engineering

B. S.

1909

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THE HISTORY OF STEEL RAILWAY RAILS

BY

WILLIAM JOSEPH WALSH

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1909

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

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Instructor in Charge.

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HEAD OF DEPARTMENT OF Civil Engineering

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INTRODUCTION

The railroad rail has received more study and more careful attention at the hands of engineers than any other track material, and it has been greatly improved and its cost cheapened. Nevertheless, it is still of vital interest to the engineer, on account of the wonderful growth of railroads, and the urgent demands of the traveling public for higher speed. For the above reasons, as well as for the safe transportation of passengers and freight, a very efficient and substantial rail is required. Moreover, there is a great future for the engineers who are able to design and produce rails which will satisfy the present requirements.

Furthermore, the steel rail is of interest to the world in general; on account of the large number of people employed in its manufacture; the necessity for safe transportation of passenger and freight traffic; and because of the vast amount of commerce which is being "carried on" at the present time.

It is also true that many of the steel rail mills are owned and operated by the great steel trust. This accounts partly for the high prices of steel rails, and the excessive tariff rates demanded by railroads, both for passenger and freight service.

In order to enumerate some of the things to be observed in the manufacture of steel rails, it would be well to begin with the primary rail and trace its development down to the present time. In the following pages, then, an attempt will be made

to follow each phase of development from the primary rail down to the modern steel rail.

DEVELOPMENT

In the development of the steel rail, there has been a constant evolution since its introduction. This was due largely to the extensive and necessary growth of railroads, and to the demands both for heavier trains and greater speed.

The first rails ever laid were wooden stringers, which were used on short roads around coal mines. The surface of these stringers were protected by wrought iron strips. Later, cast iron tramways were introduced, in which angle shaped rails were nailed to wooden stringers and flangeless rails laid on these. In 1820 the fish-belly rail was introduced and a few years later the bridge rail. In 1844 the pear-shaped rail was invented, but it was unsuccessful, owing to the difficulty in obtaining a good form of joint. The present flange or T rail section was invented by Colonel Robert L. Stevens in 1830. About the same time, the bull-head rail was introduced into England with the idea that, after one head had been worn out, the rail could be reversed and its life practically doubled. Experience has shown, however, that wear in the chairs is so great that when one head has been worn out by traffic, the whole rail is generally useless. It is also claimed that a track built of this special type of rail is better for heavy and fast traffic; but is more expensive to build and maintain. It is, however, the standard form of track in England and Europe at the present time.

Until a few years ago, there was a multiplicity in the design of T rails in this country. Nearly every prominent railroad had its own special design, which perhaps differed from that

of some other road only in very minute and insignificant details, but which, nevertheless, would require a complete set of new rolls. This certainly had a very appreciable effect on the cost of rails. Because of this fact, the American Society of Civil Engineers, in June 1893, after having obtained the opinions of the best experts of the country, decided upon a series of rail section, drawings or sketches of which will be shown in the succeeding pages. Consideration was given to the manufacturing details of rail making, as well as to the design of those forms which would be best adapted to meet the various requirements of traffic.

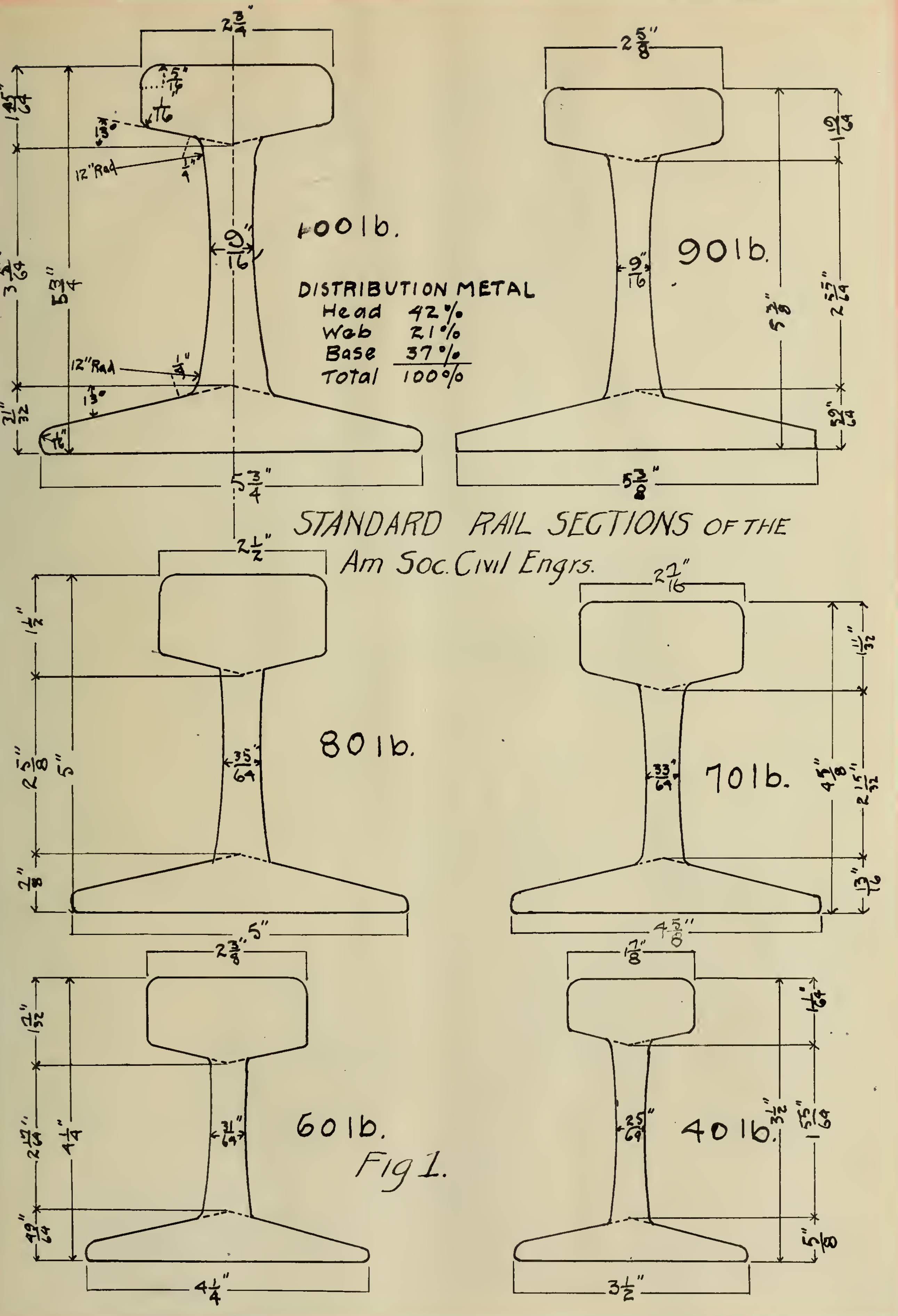
To have a smooth track, it is absolutely necessary that the surface and line of rails shall be without bumps and kinks. To obtain such rails, it is of importance that the area of the cross-section in the head and flange shall be as nearly equal as economy will permit. This allows the hot metal in the rail to cool with the least internal stress, so that when it becomes cold its form is nearly straight. This prevents excessive gagging in the final straightening. The importance of this increases with the amount of metal in the section. The quantity of metal in each part was decided upon as follows: 42 percent for the head 21 percent for the web; and 37 percent for the flange. The other constant factors were: the top radius of head, 12 inches; top corner radius of head, 5/16 inches; lower corner radius, 1/16 inch; side radius of web, 12 inches; top and bottom radius of web, 1/4 inch; angles at underside of head and top of flange, 13°.

The chief features of disagreement among railway men relate

to the radius of the upper corner of the head and to the slope of the side of the head. For it is agreed that sharp rail corners wear the wheels and produce sharp flanges which are liable to cause derailments at switches. Moreover, the tires of engine wheels are required to be more frequently turned down to their true form. On the other hand, it is generally believed that rail wear is much less rapid when the area of contact between the rail and wheel flange is small. When the rail-head has worn down (as it invariably does) to nearly the same form as the wheel flange, the entire rail wears away very quickly. The American Society of Civil Engineers has decided upon standard rail sections for the various weights of rails, and the railroads are gradually adopting them. There are a few other types such as the Dudley and Sayre sections, but they are closely related to those of the American Society's standards. (See Fig. 2).

WEIGHT

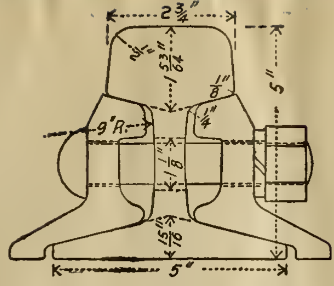
The weight is another important matter in the construction of rails from a financial standpoint. The weight of primary wooden stringers, used as rails, was 13 pounds per yard. On account of the introduction of locomotives, and the increase in weight of trains, the heavy iron rail was introduced, the first of which weighed from 40 to 50 pounds per yard. Some years ago, Mr. Sandberg began a crusade against the policy of using very light sections of steel rails. He maintained that the constantly increasing weight of rolling stock and the high speed of trains demanded a stronger track system. This, however, is not to be obtained by merely increasing the number of ties, as has been



STANDARD RAIL SECTIONS OF THE Am Soc. Civil Engrs.

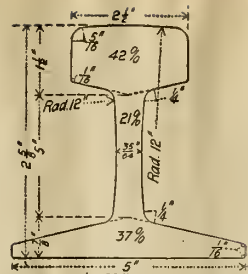
Fig 1.

[illegible]



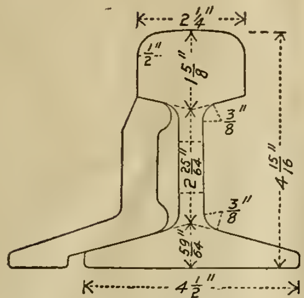
90 lbs.

~~Fig. 30~~.—Sayre Type.



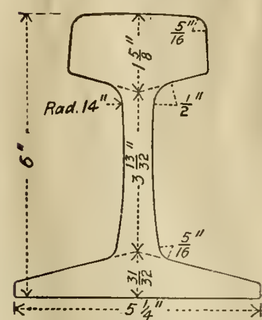
80 lbs.

~~Fig. 31~~.—Type of American Society of Civil Engineers.



72 lbs.

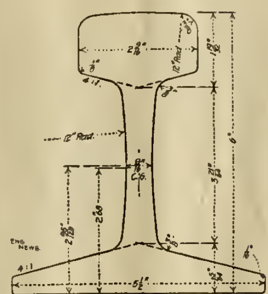
~~Fig. 35~~.—Sandberg Rail Section.



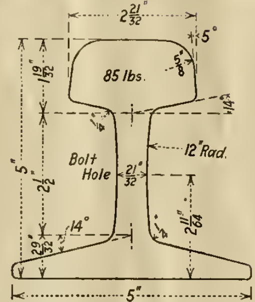
100 lbs.

~~Fig. 32~~.—Dudley Type.

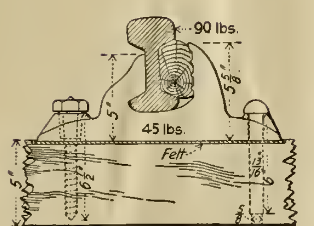
Rail Sections.



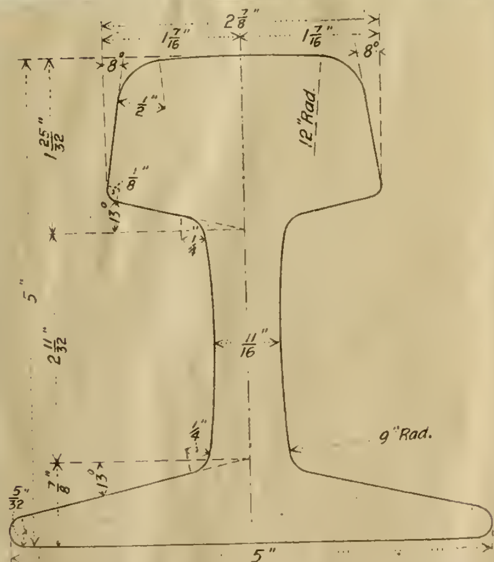
~~Fig. 33~~.—Hunt Rail Section.



~~Fig. 34~~.—Rail Section of Great Northern Ry.



~~Fig. 37~~.—Bull-head Rail and Cast-Iron Chair; London & North-western Ry. (England).



~~Fig. 1~~. Cross Section of 90-lb. Rail for Chicago & South Side Elevated Railway.

Fig. 2.

[illegible]

done in some cases, but rather by the adoption of a heavier rail. In this country, there are still many miles of rails too light for safe and economical transportation. The tendency of all roads, however, is toward an increase in weight, rendered necessary by the increase in the weight and capacity of the rolling stock. Moreover, the price of rails has been so reduced that it is both better and cheaper to obtain a more solid and durable track by increasing the weight of the rail, than by attempting to support a weak rail by an increased number of ties. It should be remembered that in buying rails the mere weight is, in one sense, of no importance. The essential things to be considered are the strength and stiffness. Let us assume that all weights of rails have similiar cross sections, which is nearly true. It is also true that in beams of similiar cross-section, the strength varies as the cube of the homologous dimensions and the stiffness as the fourth power, while the area (and therefore the weight per unit of length) varies only as the square. From this, it follows that the stiffness varies as the square of the weight, and the strength varies as the 3/2 power. As an illustration, the use of an 80 pound rail instead of a 75 pound one, adds only 6 2/3 per cent to the cost; but 14 percent to the stiffness and nearly 11 percent to the strength. This shows why heavier rails are more economical and are being adopted, even when not absolutely needed on account of heavier rolling stock.

The heaviest rail generally used in this country is the 110 pound rail of the Chegnecto Railway in Canada, but 100 pound rails are in use on the New York Central; Pennsylvania Railway;

New York, New Haven and Hartford; Chespeake and Ohio Railway, and other lines. The minimum economical weight in ordinary service is 65 pounds; but many roads have used lighter rails, even under considerable traffic.

With regard to the weight of rails in the future, they cannot be increased much without causing inconvenience in handling. Since it is not likely that much heavier rolling stock will be introduced, the writer does not expect a very marked increase in the weight of rails in the next few years. He looks forward to the time, however, when most of the railroads will be using the 100 pound rail.

LENGTH OF RAILS

Another item of interest in the history of rails is the standard lengths that have been adopted from time to time. The primary rail--the wooden stringer--was 12 feet long. The cast iron rails introduced later were only 3 feet in length. Still later, the 18-foot wrought iron rail was brought into use. In 1855, when steel rails were introduced, the standard length was 30 feet. Just why 30 feet came to be universally adopted as the standard length is not a matter of record, but it may readily be surmised that convenience of transportation had considerable to do with it. For many years the ordinary length of flat cars was such that a rail longer than 30 feet could not be conveniently handled thereon in shipment; and it is also probable that in the early rolling mills, a sufficient quantity of metal for making a rail longer than 30 feet could not be handled in a single ingot. However, such difficulties no longer exist, but the 30-foot rail

remains the standard.

In recent years, many roads have been trying the 45-and 60-foot rails. The argument in favor of longer rails, is chiefly that of reduction in rail joints, which are costly to construct and maintain, besides being a fruitful source of accidents. Mr. Morrison of the Lehigh Valley Railroad, in his report to the Roadmasters Association of 1895, declares that as a result of extensive experience with 45-foot rails on that road he finds that they are very much less expensive to handle, on account of their length, and can be laid around sharp curves without being curved in a machine as is necessary with the shorter rails. The great objection to longer rails lies in the difficulty experienced in allowing for expansion, and the inconvenience in transporting and handling them. Both the Pennsylvania and the Norfolk and Western Railroads have a great many miles of 60-foot rails. Almost all the street railways have adopted this length, as there is no difficulty encountered in allowing for expansion, the rails being welded together and made continuous.

Rails 33 feet long are extensively used on many roads, and an increase in the standard length to 33 feet has been recommended by the Roadmasters and Maintenance of Way Association, and by the American Railway Engineering and Maintenance of Way Association. Rails longer than 33 feet have been used on comparatively few roads.

In Germany, the old standard length for rails was 29 1/2 feet, and the experience derived from increasing the length seems to have resulted more satisfactorily than has been the case in this country. An increase in 33 1/2 percent, or to 39 feet 4

inches, seems to have met with general approval, whereas on some roads the standard length has been increased to 59 feet.

Until some method which will allow for expansion is found, there will probably be no increase in the standard length adopted in the future. Moreover, it is rather difficult for a few men to replace 45 or 65 pound rails, because it is often necessary to haul rails more than a quarter of a mile on a hand car, which is very inconvenient and dangerous. It is more than likely, however, that the 33-foot rail will be adopted as the standard, since it is less expensive than the shorter rails.

COMPOSITION

As has been stated before, there has been a marked change in the composition of rails. The first rails were composed of wood, usually a high grade of oak or pine. At this time, timber was plentiful and hence the best was used. With reference to the composition of cast and wrought iron rails, little is known. Formerly little attention was paid to the chemical composition of the rail. Early rails, which wore remarkably well, showed on analysis a wide variation in chemical constituents. Carbon ranged from .24 to .70 percent and phosphorus .08 to .16 percent. The mill processes, however, were performed slowly and carefully. The rail heads were small, and the rails were worked at so low a temperature that they came out hard and tough. It mattered little, therefore, about the carbon or the other chemical constituents. As time passed, however, the demand for rails increased, prices fell, and the mill outputs grew rapidly. For this reason, the manufacturers became less careful. Rails were furnished hotter,

and were of an inferior quality, and then the chemistry of the rail assumed more importance.

About 1818 Dr. C. B. Dudley, chief chemist of the Pennsylvania Railroad, announced that soft rails were best. His conclusions were based on 25 samples of rail, taken out of the track, and his critics maintained that this was too small a number to serve as a basis for a general law. In 1880, he came forward with a second paper, a long, carefully written and ingenious report to the superintendent of motive power. In this, he based his conclusions on 64 samples, and he advocated the same theory as before, namely, that rails low in carbon were the best. The practical outcome was that this proposition was accepted and supported for years. He recommended to the Pennsylvania Company a specification regulating the chemical constituents as follows: carbon .25 percent; phosphorus .10 percent or less; silicon .40 percent and manganese .30 to .40 percent. It is doubtful if carbon is ever placed as low as .30 percent. The Dudley specification was succeeded by one requiring .30 to .40 percent of carbon and giving a wider range to the chemical constituents.

But the Dudley specification made people timid about a high carbon rail. The theory, however, was not born out by experience, nor was it demonstrated by Dr. Dudley's figures. The rails, which he considered, were not of high carbon content. Of the 64 samples, only one had over .60 percent of carbon, and only four contained more than .50 percent. But today, 50 percent of carbon is regarded as only a little above the average.

More carbon is usually specified and a rail having only .45 percent would not be ranked as hard; while twenty years ago a carbon rail of .50 percent was considered ample in the United States. In French practice, it would have been considered low. For the French consider no rail hard unless it has more than .50 percent of carbon, and they often use 1.00 percent. Mr. Conard, a French engineer, found from a study of rails turned out by various French mills that their composition averaged as follows: carbon .86 percent; manganese .69 percent; silicon .15 percent; and phospherus .05 percent. He compared these with a number of rails manufactured by five German mills averaging .31 percent of carbon and .09 percent of phosphorus, and found that the French rails wore about twice as long as the German rails.

In the present rails, carbon ranges proportionately as follows: 60 pound rails .40 to .45 percent; 70 pound .45 to .50 percent; and 80 pound .45 to .60 percent. The maximum is .65 to .75 as specified for the 100-pound rail of the New York Central Railway, but it is rarely, if ever, that .70 percent is exceeded. The object of carbon is to give hardness to the steel, but it is liable to render it brittle unless special care is taken in proportioning the other chemical constituents.

The analysis of 32 specimens on the Chicago, Milwaukee and St. Paul Railroad shows the proportion of chemical composition as follows:

Carbon 0.211 to 0.52 percent;

Silicon, 0.13 to 0.256 " ;

Phosphorus, 0.055 to 0.181 percent:

Manganese, 0.35 to 1.63 percent.

Carbon up to one percent increases hardness and tensile strength but decreases the ductility and toughness. It was formerly used in small proportions, but in late years the tendency is for more carbon to increase the hardness which is required to meet the increased wheel pressure.

Manganese is necessary to take up the oxides of iron while the metal is in the molten state. In sufficient quantity, it assists toward a more uniform distribution of the carbon through the iron. It also facilitates the chemical combinations of the iron at high temperatures, and tends to prevent separation into graphite as the iron cools. If not used to excess, it imparts strength and toughness. If the iron is low in carbon, the effect of manganese is similar to that of carbon alone; but diminishes the ductility in less degree. It may, therefore, replace the carbon to some extent, and is considered an effective antidote for sulphur. When used in high percentage, it has the effect of making the rail hard and coarsely crystalline, and its tendency is to brittleness when it exists in unnecessary quantity. We, therefore, see how important this constituent has become. Its use varies according to circumstances from .70 to 1.4 percent.

Silicon is another useful ingredient and it is gradually becoming recognized as an important element. It acts as a flux, and like manganese tends to prevent injury by oxidation of the iron. When of just sufficient quantity, it gives added toughness, but any increase beyond this tends to produce brittleness. It has a hardening effect, and to a limiting extent may replace

carbon. Its present use ranges from .10 to .20 percent.

Sulphur and phosphorus are both objectionable elements, but are difficult to extract from the metal. They perform no useful service in combination which is not secured by other elements. Their quantity, however, must be kept at a minimum; sulphur not to exceed .07 percent, and phospherus not to exceed .085 percent. Rails which have a high percent of either should not contain a large amount of carbon. Prior to the last ten or fifteen years, these constituents have received little attention, only recently has it been advocated that a small amount of these adds to the strength of the metal.

Traces of copper have been found in rail steel, and it sometimes runs as high as 0.8 percent, altho specifications do not usually require it or place limitations upon the percentage used. In small quantities, it slightly raises the tenacity and elastic limit without tendency to brittleness, but reduces the toughness. This effect, however, is not pronounced when the quantity is small.

Chemical specifications are at present considered only an approximate guide, because much depends upon the mechanical and heat treatment of the metal during the process of manufacture. In late years, chemical specifications have not been considered as important as they once were. More stress is now being laid upon the production of rails to meet certain tests of strength and stiffness. There is more attention paid to a guarantee of serviceability for a stated period than to the chemical composition. It has become the custom of many roads to leave the

chemical composition within wide limits, or entirely to the discretion of the manufacturer.

The process of manufacture of steel rails is becoming more important. The first iron rails were made from straight puddled bars. These were about one inch thick, and were placed one upon another until a pile of sufficient weight and height was formed. The pile was then reheated and rolled into rails, and it was to the formation of that pile that inventive genius was applied.

At one time, a rail with a puddled steel head - or rather with the top bar of the pile of puddled steel - found much favor, but owing to the difficulty of obtaining uniformly good welds, the results were not satisfactory.

Another plan, upon which much money was spent, was to hammer a puddled ball or to weld two puddled balls together under a steam hammer. These were then drawn into a slab two to two and one-half inches thick, which was placed on the top of the rail pile. The Pennsylvania Railroad ordered several thousand tons of these rails, but their service was somewhat disappointing and their use was abandoned.

Later the railroads adopted the system of having the old rails rerolled into new ones. At first a certain percent of new iron was specified, but as the necessity for immediate economy increased, that demand was no longer made and new rails were composed entirely of old ones.

From the many reworkings of rails, the cheapening of the process of manufacture, and the necessary demands of traffic, the ability of the iron rails to resist wear became more and

more unsatisfactory. It then seemed that from this cause alone the limit of railway development had been reached. The solution of the difficulty was the introduction of the Bessemer process.

We all realize that without such an innovation as Bessemer's, the subsequent tremendous expansion in railway development would have been physically impossible. The first rail ever made by the process was placed on the Midland Railroad of England in 1857 and remained until 1873, some sixteen years, during which time about 2,250,000 trains passed over it.

The material essential to anything like a comprehensive description of the various processes of manufacture of steel rails would swell convenient limits of space in this work; hence only the changes which have taken place from time to time will be mentioned.

The first Bessemer steel was produced by an experimental plant at Wyandotte, Michigan, in 1864. It was first introduced by A. L. Halley, Its invention led to a greatly increased facility of manufacture and a consequent decrease in the cost of steel rails. This process with Halley's improvements and the invention of the Siemens-Martin method of manufacture, and the consequent introduction of rails at reasonable prices, were great factors in the enormous railway development of the last 25 years. The cheapness and rapidity of manufacture, however, have to some extent received more attention than the composition.

In 1867, George Fritz, then chief engineer of the Cambria Iron Company, Johnson, Pennsylvania, invented the blooming mill on which steel ingots are rolled instead of reducing them by

hammering, as had been the practice. Mr. Fritz built his first regular three-high blooming mill in 1871. This departure from the old practice (added to Halley's modified converting plants) greatly helped to increase production.

During the Civil war there was a great demand for cheap steel. An answer to this universal demand was made by the inventive genius of two men - William Kelly, an Irish-American of Pittsburgh, and Sir Henry Bessemer an Englishman of London. They devised a new way to refine iron, which has since been known as the Bessemer process. Their discovery was an entirely new idea, and one which at first seemed absurd to every other steel-maker. Within a few years, however, it was universally adopted, revolutionizing the iron and steel trade and providing the world with a cheap and abandunt supply of its most useful metal.

In 1851 the first converter was built - a square brick structure, four feet high, with a cylindrical chamber. The bottom was perforated for the blast. The greatest difficulty was to obtain a sufficiently strong blast.

The second converter was made with holes in the sides, and after this, one improvement followed another. Kelly built seven converters in a backwoods hiding place and his eighth, a telling converter, was built in the Cambria Iron Works. With this converter, he showed that cold air does not chill molten iron but refines it with amazing rapidity if blown through it for the proper length of time.

The new process was perfected by a third inventor, Robert Mushet, who solved the problem of how to leave just enough carbon

in the molten steel to harden it. Instead of trying to stop the process at the right moment, Mushet asked; "Why not first burn out all the carbon, and then pour back the exact quantity you need?" This was a simple device but no one had thought of it before. Since then, other improvements have been added by Halley, W. R. Jones, Reese, Gilchrist, and Thomas.

The new metal was soon called "Bessemer steel." Strictly speaking it was not steel but much like wrought iron. It was not hard enough to serve for all purposes.

The modern converter is a huge iron pot about twelve to fourteen feet high. It swings on an axle so that it may be tilted up and down. About 30,000 pounds of molten iron are poured into it, and a strong blast of air is then forced through the perforated bottom, which rushes through the metal with great rapidity. Then yellow sparks are sent out at the top many feet into the air. The converter roars like a volcano in eruption. The impurities in the iron - phospherus, silicon, sulphur and carbon - are separated from the metal. The sparks change from red to yellow; and then suddenly become white. At this juncture, the converter is tilted sideways. A workman now charges it with several hundred pounds of carbon mixture to restore the necessary elements that have been blown out. It is then tilted further, and the molten iron is poured into a swinging ladle and from this into a train of huge clay pots, pushed into place by a little locomotive.

Another improvement in the manufacture of steel rails was the mechanical appliances added to the rolls by Robert Hunt. Until March 1884, all American rails were fed by the use of

hooks and tongs. Three high trains required from fifteen to seventeen men for a production of 300 tons in twelve hours. numerous inventors up to that time had sought to accomplish this work by machinery which would be automatic in its action, but none had been actually built. In 1884 tables were driven in front of the finishing rolls of the rail train of the Albany and Rensselaer Iron and Steel Company of Troy, New York. This worked so well that an automatic arrangement was put in front of the roughing rolls.

It was not until 1899 that the commercial manufacture of rails from basic open hearth steel was introduced. Aside from their comparative merits, the quantity of acid and basic open hearth rails rolled in the United States in 1905 is small as compared with the Bessemer tonnage. There have been two attempts to make steel in America by the basic Bessemer process. Both were technically successful, but owing to the character and cost of the obtainable iron, failed commercially.

Most of the present rails are made by the Bessemer process. It is true, however, that a large number of rails fail in service and it is probable that the number of broken rails would be considerably reduced if they were made of open-hearth steel.

The question, therefore, arises why more rails are not made of this material, and railway engineers occasionally come forward with inquiries to that end. It may be well to say, therefore, that the making of open-hearth rails is purely a commercial question and involves immense sums of money. Most of the rails made in America today are made by the Bessemer process, and each rail making plant must be regarded as a unit.

The converting department is one factor, its capacity and whole scheme of operation being designed for the one purpose of supplying the blooming mill with just the right quantity of ingots, at just exactly the right size. It may happen that at a given rail making works there is no open-hearth furnace plant at all.

Many are aware of the fact that small lots of open-hearth rails may be made, but their production on a large scale means a plant laid out with that end in view. Moreover, if this plant does not have a regular line of business extending over many years at an increased price, it will be a loosing venture. Within the last few years it has been clearly shown that a great improvement may be made by certain modes of heat treatment. Much care is now taken to finish the rails colder than formerly, and to do a great deal of work on them while they are at a moderately low heat. By so doing, a much better grain is attained, and this renders possible the use of a higher content of carbon than was formerly thought advisable. This question of finishing temperature and all the associated problems of wear and toughness are being thoroughly threshed out, and it may be well to await the results of experiments now under way before starting out into untried fields. The open hearth rails seem to be of better quality than those made from Bessemer steel, but the future rails are likely to be made by the Bessemer process owing to the reasons given above.

The hardening and toughening effect of alloying steel with nickel, so successfully practiced in the manufacture of armour plate, has naturally suggested a like treatment for rail steel. Such experiments are now being conducted on a small scale with

steel made both by the Bessemer and open hearth processes. On the Pennsylvania lines, some nickel-steel rails were laid on a five degree curve, and after four years of service were said to be wearing better than rails of ordinary steel. Experimental use of nickel-steel rails for six years seems to indicate that rails of such metals will out wear three or four sets of carbon-steel rails. Nickel-steel rails laid in a freight track of the Pennsylvania Railroad at Kilanning, Pennsylvania, lasted three years, as against 10 months for ordinary steel rails.

In addition to the roads mentioned, the following are experimenting with nickel-steel rails; Bessemer and Lake Erie Railroad, the Union Railroad, and the New York Central and Hudson River Railroad.

The chemical composition of these rails was found to be as follows: carbon, .418 percent; silicon, .102 percent; manganese, .79 percent; phosphorus, .094 percent; and nickel, 3.38 percent. Some frogs and switch points of the same steel are also under trial.

DURABILITY

An investigation was begun some time ago at the test department of the Philadelphia and Reading Railway to determine the elements in steel rails which caused fracture or relatively rapid wear; and to work out the means necessary to reduce these to a minimum.

A considerable number of rail-sections which were fractured in track or which were removed owing to very rapid wear were examined in order to gain the desired information. A consider-

able number of rails which gave good results in service have also been tested in the hope of finding fundamental characteristics which might account for the durability or the failure, as the case might be. Also in the regular rail inspections at the mills, sections representing the various methods of manufacture have been taken, and particular attention has been given to investigation of the differences between rails which failed under the drop test and those which passed it successfully.

It was believed then, as it is now, that a proper chemical composition is one of the essentials for obtaining the greatest durability in steel rails. This theory was confirmed by other investigators, and they proved that physical character and structure have at least an equal influence upon the final outcome.

Up to the present time, about 200 defective rails have been examined. In some cases complete chemical analysis have been made; and in others the loose, coarse grained fracture or other physical character - such as piping - showed the cause at a glance; and in still others, a rather elaborate investigation was necessary to prove the matter to a certainty.

In a general way, the results of analysis in this investigation have merely confirmed the previous opinion, and have proved beyond question that specifying chemical composition alone insures neither a durable nor inefficient rail. From the start, a marked difference in structures was found, and the following characteristics in the rails which gave defective service were noted:

(a) Coarse, regular, granular structure; and

(b) Excess of foreign matter, such as oxides, slag and

enclosed gases. Either of these resulted in relatively poor service.

On the other hand, in rails of the same general composition giving satisfactory service, a generally fine interlocking broken granular structure with relative freedom from foreign matter and gas was found. By a comparison of the above results with those obtained in other mill inspections, complete accordance was found. The rails similiar to those of the first type proved exceedingly fragile under the drop test of 2000 pounds, falling 20 feet. In contrast to this, rails of the latter class showed a marked toughness under the drop test, and one stood 14 blows of the drop test without fracture, being turned after the first blows, and succeeding odd numbers.

These marked differences confirm the work of others. Mr. J. E. Stead for instance saya, "It is clear that the junctions (of the grains) are a safe guard, and the more junctions there are, the more reliable will the steel be." And again,"it would seem to follow, then, that the smaller and finer the grain the safer the structure." This coincides with the researches of Brinell, Sauveur, and others.

It is a common saying that the wearing qualities of rails made during the late years, particularly the rails of heavier section, have been disappointing; that they do not compare with the service obtained from the 50-pound rail rolled about 1880. The reasons explanatory of this experience have been discussed until the situation is quite generally understood. Making due allowance for the effect of the largely increased wheel loads and train speeds, the currently accepted views of the situation

may be summed up briefly in the following statement. Competition and the desire of the railway companies to purchase rails at the lowest possible price have forced the manufacturers to resort to quicker and cheaper methods of handling the metal and to cheapen the cost in the process of rolling. The result was that rails were finished at too high a temperature to obtain the benefits of the rolling action on the steel, or the "working" of the steel as it is called. In course of time the competition largely disappeared, and the manufacturers fixed their own price for rails, but the quality of the metal was not improved.

Foreign matter in the rails decreases its durability. As to the origin of these impurities in steel, it is evident that they must be due to defective mill practice, either in the manufacture of the steel, including teeming and settling; in burning of steel in soaking pits, or in blooming furnaces if the latter are used, or in cropping blooms or rails. In any event the short life of those rails is an unquestioned proof of defective mill practice.

In order to insure the most durable rail of a given composition, the above investigations indicate that there must be,-

(1) Freedom from brittleness,

(2) Absence of unsoundness.

(3) Fine granular structure.

Chemical and mechanical tests are both necessary for a thorough determination of the value of the rail. Until the introduction of the steel rail, there was little, if any, testing made upon rails. The chemical test has for its main object the determination of those minute quantities of chemical elements

which have such a marked influence on the rail for good or bad. The mechanical tests consist of the usual tests for elastic limit and ultimate strength. The elongation at rupture is determined from pieces cut out of the rails. One of the chief tests used is the "drop test". This consists in dropping a weight of 2000 pounds from a height of 16 to 20 feet upon the centre of a rail, which is supported on abutments, placed 3 or 4 feet apart. The number of blows required to produce rupture, or to produce a permanent set of specified magnitude, gives a measure of the strength and toughness of the rail. In order to pass the test, the butt is supposed to withstand one blow from the falling weight without breaking. The test also requires that the rails shall not bend more than 6 inches, and upon reversal must stand, without breaking, a blow on the convex side from the 2000 pound weight falling through half the standard height, or 8 feet to 10 feet.

In this country the testing of rail metal for tensile strength is not in general practice but test pieces from rail steel of good quality will usually show an elastic limit of 55,000 to 65,000 pounds per square inch, and an ultimate strength of 110,000 to 120,000 pounds at breaking. The test piece should have an elongation of 12 to 15 percent in a specified length usually 8 or 10 inches and a modulus of elasticity of 29,000,000 to 30,000,000 pounds.

In this country, moreover, no tests for hardness are imposed, but the physical hardness may be quite closely determined from the chemical hardness, namely by the determination of the amount of carbon and phosphorus present. Some attempts at

measuring degrees of hardness have been made by an observation of the indentations on the rail of loaded knife edges of hardened steel; but the use of such tests and others of a different character does not seem to have passed the realm of experimentation.

There was a practice at one time, prevalent among manufacturers of rails, by which the makers guaranteed to replace all worn or broken rails that had to be renewed within a certain period (usually five years). No such guarantees are now given, and at most the makers agree to replace broken rails which show actual flaws. It is generally recognized that methods of manufacture should be left largely to the discretion of the maker, the rails being carefully inspected and tested on behalf of the purchaser. Under present conditions, there is practically no control of the manufacture; the mills very generally decline to make rails fulfilling the requirements of the railways, but furnish those made according to the specifications adopted by the manufacturers.

In the future, the writer expects more control of the manufacture of rails by the maker, but more severe tests on the part of the purchaser.

GROWTH STEEL INDUSTRY

In June 1876 there were ten rail mills in operation and an eleventh nearly ready to start. At that time one Bessemer Company had already become bankrupt; and two of these companies and their works have absolutely gone out of existance. In fact, but five of these are now making rails. Since 1876, in addition

to those already mentioned, 18 corporations have erected mills to roll standard weight steel rails, 14 from steel of their own manufacture and four from purchased blooms. Seven of the steel producers are now making rails, two are on other products, and the remaining nine have gone out of existance, so that there are now in the United States 10 corporations running 13 rail mills. The above refer only to the mills that are rolling rails of 60 pound or more to the yard. Three of the companies are controlled by one corporation, three others by another, and two others by still another; thus leaving two single and independent concerns. In addition, the building of another mill of large capacity to roll basic open hearth rails, together with the required blast furnaces, steel furnaces, and town, has just been completed.

In June 1876, the Bessemer plant of the North Chicago Rolling Mill Co., built from Halley's plans, then in charge of Robert Forsyth, held the record for a month's production of ingots at 6457 gross tons. The production in the whole United States in 1876 was 469,639 gross tons of Bessemer ingots, from which 368,299 gross tons of rails were made.

There was a constant increase in output until 1887, when the production of ingots reached 2,936,035 tons, and of rails 2,101,904 tons. It was not until 1899 that the production again passed the 2,000,000-ton point. In that year there were turned out 7,586,354 tons of Bessemer, 2,947,316 tons of open hearth ingots and 2,270,585 tons of rails all of Bessemer steel. Following that year, there was a continued increase in the output of open-hearth steel, while that of Bessemer remained more

nearly constant. In 1905, 10,919,272 gross tons of Bessemer steel, 8,444,836 gross tons of open hearth ingots, and 3,375,611 gross tons of rails were made, 183,264 tons of which were of basic open hearth steel.

The North Chicago Rolling Mill Company, which held the monthly record for product of Bessemer ingots in 1876, built in 1882, an entirely new Bessemer and rail plant at South Chicago, some fifteen miles away from its old one. There have been changes in the management and additions to the plant since then, but fundamentally, the converting works and mills are the same, and their record production is 91,424 gross tons of ingots and 71,424 gross tons of rails in a month. All of these rails were rolled on one rail mill.

In 1886, the rail mill of the Edgar Thompson works had been doing very commendable work, but it was being pressed in output by other mills. A new mill was started in 1888 and all promises for it have been much more than fulfilled. Its greatest production of rails for a month is 61,033 gross tons. There are three sets of rolls in this mill, which are placed in a tandem formation. The converting works have made 102,740 gross tons of ingots in a month, all of which were reduced to blooms on one three-high blooming mill. After the starting of the new mill the original Edgar Thompson rail mill remained idle for several years. It was then remodeled and used for the production of rails which were under 60 pounds per yard in weight. This mill has been in constant operation ever since.

In this connection, it would be well to give some statistics in regard to the production of pig iron. In 1876 the production

of pig iron of all kinds in the United States was 1,868,961 gross tons. In 1905, it was 22,992,380 gross tons. The production of Bessemer pig iron was separated statistically from other pig iron until 1887. In that year it was 2,875,462 gross tons; and in 1905 it was 12,279,462 gross tons. The production of basic pig iron was first ascertained in 1886 when it was 336,403 gross tons. In 1905, it was 4,105,179 gross tons, charcoal basic pig iron not being considered in either case.

The writer does not look for a more marked increase in the output of pig iron and steel in the future. In fact it seems to have reached its limit. The sources of iron ore are becoming exhausted and new sources are rare. Many of the new ore deposits contain sulphur and the ore is mostly iron pyrites which is very costly to purify.

The steel industry is of vast importance to us because of its employment of so many people. The Illinois Steel Company of Chicago, which is a comparatively small steel industry, employs more than 8,000 men. But, owing to the recent panic, the working force was reduced by several thousand.

Most of the steel concerns in this country are owned and operated by one of the larger companies, the Carnegie or Cambria steel corporation. We are led to think that perhaps almost all are under the control of the steel trust. Hence this should be of much interest to the public. Of course, these combines have their advantages as well as their disadvantages but in the opinion of the writer they should be under the direct control of the people.

CONCLUSION

In conclusion, the author ventures to say that for many years to come, the standard rail for the United States and for most of the civilized world will be about such a rail as we are now using. The section will not differ greatly from that which has already been decided upon; that is, the Dudley-Hawks-Hunt-American Society of Civil Engineers section. The average weight will very likely be more than it is now, and the steel harder. The writer should not be surprised to see 100 pounds per yard common, 80 pounds the average weight, and 0.60 percent the average of carbon content. This rail may be 60 feet long, and possibly 90. By making it 60 feet long, we eliminate half of the rail joints - the most troublesome item of a railroad track. In fact, the Pennsylvania Railroad, the Norfolk and Western, and some other roads are today putting in many 60-foot rails.

In all that has been said in the preceding articles, the subject has been merely touched upon. There is much more to be said regarding steel rails and their development but the writer has aimed to give a clear and brief account of the history down to the present time.

The writer agrees with Mr. Prout when he says, "If the young engineer will candidly and courageously, modestly and without pedantry, study the scrap heap, I think we can predict for him a reasonable measure of success. Whether or not he succeeds in getting money or distinction, that way of meeting the problems of life will secure the respect and esteem of the best men about him, which, after all is the highest success

success that can be hoped for."

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